Software Engineering Institute

Software Product Lines: Report of the 2009 U.S. Army Software Product Line Workshop

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Acknowledgments

The workshop organizers would like to acknowledge the outstanding work of Barbara Pemberton, PEO STRI, in hosting this workshop, and Carolyn Kernan of the SEI for being the workshop co-ordinator.

Abstract

The Carnegie Mellon Software Engineering Institute held the U.S. Army Product Line Practice Workshop on February 12, 2009. The workshop was a hands-on meeting to share Army and DoD product line practices, experiences, and issues and to discuss specific product line practices and operational accomplishments. Participants reported encouraging progress on Army software product lines. This report synthesizes the workshop presentations and discussions.

1 Introduction

1.1 Product Line Practice

A *software product line* is a set of software-intensive systems sharing a common, managed set of features that satisfy the specific needs of a particular market segment or mission and that are developed from a common set of core assets in a prescribed way [Clements 2002]. An increasing number of organizations are building their products as product lines in order to achieve large-scale productivity gains, improve time to field or market, maintain a market presence, compensate for an inability to hire, leverage existing resources, and achieve mass customization.

In January 1997, the Carnegie Mellon® Software Engineering Institute (SEI) launched the Product Line Practice Initiative to help facilitate and accelerate the transition to sound software engineering practices using a product line approach. The goal of this initiative is to provide organizations with an integrated business and technical approach to systematic reuse, so they can produce and maintain similar systems of predictable quality more efficiently and at a lower cost.

A key strategy for achieving this goal has been the creation of a framework for product line practice. The SEI *Framework for Software Product Line Practice*℠ (henceforth referred to as "the framework") describes the foundational product line concepts and identifies the essential activities and practices that an organization must master before it can expect to successfully field a product line of software or software-intensive systems. The framework is a living document that is evolving as experience with product line practice grows. Version 4.0 is described in the book *Software Product Lines: Practices and Patterns* [Clements 2002], and the latest version is available on the SEI website [Northrop 2009b].

The framework's contents are based on information-gathering workshops,[1] extensive work with collaboration partners, surveys and investigations, and continued research. The SEI has also incorporated practices reported at its international Software Product Line Conferences and collected from the community [Donohoe 2000, Chastek 2002a, Nord 2004, Obbink 2005, O'Brien 2006, IEEE 2007, Geppert 2008].

In March 1998, the SEI hosted its first Department of Defense (DoD) product line practice workshop, Product Lines: Bridging the Gap—Commercial Success to DoD Practice [Bergey 1998]. Topics discussed and documented included DoD barriers and mitigation strategies, and similarities and differences between DoD product line practice and commercial product line practices.

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1 The results of some of these workshops are documented in SEI reports [Bass 1997, Bass 1998, Bass 1999, Bass 2000, Clements 2001].

Subsequent workshops were held in successive years [Bergey 1999, Bergey 2000a, Bergey 2001, Bergey 2003, Bergey 2004, Bergey 2005].

At all seven DoD workshops, the SEI was encouraged to continue holding DoD workshops and to continue sharing best commercial and DoD practices through these forums. In 2006 the workshop was held as a "birds of a feather" session in conjunction with the International Software Product Line Conference, SPLC 2006, in Baltimore, Md. In 2007, sponsorship switched to the Army Strategic Software Improvement Program (ASSIP) under the auspices of the Assistant Secretary of the Army for Acquisition, Logistics and Technology [ASA (ALT)].This 2009 workshop was the second Army Workshop sponsored by ASSIP.

1.2 About This Workshop

The goals of the February 2009 Army Software Product Line Workshop were to

- share Army and DoD product line practices, experiences, and issues, from both development and acquisition viewpoints
- examine barriers and enablers to much broader adoption of software product line practices within the Army
- determine the steps needed to make software product line practices more beneficial and relevant to Army programs
- discuss ways in which the ASSIP can be of assistance

All participants in this workshop were from the DoD acquisition and contractor community; there was one university affiliate. They were invited based on our knowledge of their experience with and commitment to software product lines as either DoD system acquirers or DoD system contractors. Together, the group discussed the issues that form the backbone of this report.

The format of this workshop followed that of the previous successful workshops. Invited presentations were followed by a facilitated discussion of ideas stimulated by the presentations. The group agreed that this format worked well.

The workshop participants included

- Ceci Albert, Acquisition Support Program, SEI
- John Allen, Nova Technologies
- Ron Asan, U.S. Army, Sequoyah
- John Bergey, Research, Technology, and System Solutions Program, SEI
- Allan Bond, General Dynamics C4 Systems
- Thomas Burke, Bearing Point
- Sholom Cohen, Research, Technology, and System Solutions Program, SEI
- Patrick Donohoe, Research, Technology, and System Solutions Program, SEI
- Edward Dunn, U.S. Navy Naval Undersea Warfare Center (NUWC)
- Terry Gatewood, U.S. Army, AMRDEC, C-RAM Program Office
- Paul Jensen, Overwatch Textron Systems

- Lawrence Jones, Research, Technology, and System Solutions Program, SEI
- Brian Kemper, U.S. Army PEO STRI
- Jerry Kunert, U.S. Army RDEC CERDEC SEC, Prophet
- Reed Little, Research, Technology, and System Solutions Program, SEI
- Christal Martir, Lockheed Martin STS (CTIA)
- Michael McMahon, CACI (Sequoyah)
- Dana Miles, U.S. Army, RDECOM CERDEC SED
- Khuc Nguyen, U.S. Army PEO STRI
- Linda Northrop, Research, Technology, and System Solutions Program, SEI
- Roger Olsen, Nova Technologies
- Daniel Oshea, Lockheed Martin STS (CTIA)
- Barbara Pemberton, U.S. Army PEO STRI
- Rakesh Rana, U.S. Army Armament Software Engineering Center
- Stephen Rivera, Advanced Systems Technology, Inc
- Philip Russel, Northrop Grumman Mission Systems
- William Samper, U.S. Army PEO STRI
- Dirk Sarner, U.S. Army IAMD Project Office
- Robert Schwenk, U.S. Army ASA(ALT)
- Les Simon, U.S. Army PEO IEW&S
- Donald Snelgrove, BAE Systems
- Steve Snell, SAIC
- Michael Szydlowski, U.S. Army Weapons Software Engineering Center (WSEC)
- James Todd, U.S. Army PEO STRI
- Damla Turgut, University of Central Florida

1.3 About This Report

This document summarizes the presentations and discussions from the workshop. This report is written primarily for those in the DoD who are already familiar with product line concepts, especially those working on or initiating product line practices in their own organizations. Acquisition managers and technical software managers should also benefit from this report. Those who desire further background information are referred to the following resources:

- *Software Product Line Essentials* [Northrop 2008]
- *Basic Concepts of Product Line Practice for the DoD* [Bergey 2000b]
- *A Framework for Software Product Line Practice, Version 5.0* [Northrop 2009b]
- *Software Product Lines: Practices and Patterns* [Clements 2002]

The next section of this report contains a digest of the presentations. A summary of the facilitated discussions follows. The report concludes with a brief summary.

2 Software Product Line Experiences: A Digest of Participant Presentations

2.1 Introduction – Linda Northrop, SEI

Linda Northrop, Director of the Research, Technology, and System Solutions Program at the SEI, began by explaining the workshop goals and agenda. She then gave an overview of software product line practice. As previously noted, readers who would like an explanation of the basics of software product lines should see the references in Section 1.3 or Linda's workshop slide presentation [Northrop 2009a].

2.2 A Proactive Software Product Line Acquisition Approach – John Bergey, SEI

John Bergey of the SEI presented a proactive approach for acquiring a product line in the DoD environment. A product line approach presents some unique challenges to DoD programs. It involves adopting a new set of practices, specifying an appropriate division of responsibilities, and contracting with suppliers to develop, operate, and sustain a product line. The product line aspects are specified up front—precluding opportunistic attempts to initiate a product line approach under an existing contract—so that an appropriate set of requirements and SOW (statement of work) tasks can be included in the RFP (request for proposal) and the contract.

2.2.1 Alternative Acquisition Approaches for Acquiring Products via a Product Line

There are three basic approaches:

1. **A PM commissions a government organization to develop a product line.** This strategy involves acquiring a government-owned product line (production capability and products) using the in-house capabilities of a designated government acquisition organization.[2] An example is the Army's Advanced Multiplex Test System (AMTS) [Cohen 2007].
2. **A PM commissions a contractor to develop a government-owned product line.** This strategy involves acquiring a government-owned product line (production capability and products) from a contractor.
3. **A PM commissions a contractor to develop products using the contractor's proprietary product line.** This strategy involves acquiring products directly from a contractor that has an existing product line. An example is the Textron Overwatch Intelligence Center (OIC) product line [Jensen 2009].

The difficulty in executing these different strategies varies significantly and requires different levels of management sophistication and technical skills on the part of the acquisition organization. Related considerations include the data rights to product line artifacts and the risk of a supplier's going out of business.

[2] This may include using the services of local Systems Engineering and Technical Assistance (SETA) contractors.

2.2.2 Conceptual View of a Product Line Acquisition Example

The two basic elements of a software product line acquisition (Figure 1) to be commissioned are

1. the development of a product line production capability
2. the subsequent development of a family of software products using that production capability

The product line production capability includes product line core assets and the production plan that enables products to be built in a prescribed way. A production plan prescribes how the products are produced from the core assets. It includes the process to be used for building products and lays out the project details to enable execution and management of the process (e.g., by including such details as the schedule, bill of materials, and metrics). An additional document, the product line concept of operations (CONOPS), describes the organizational approach for operating the product line effort, the organizational structure, and the roles and responsibilities of the stakeholders in product line operations. It also describes the interconnections among those involved in the product line effort, including communication mechanisms, decision and conflict resolution processes, a document map, and any supporting Web site or wiki for the product line.

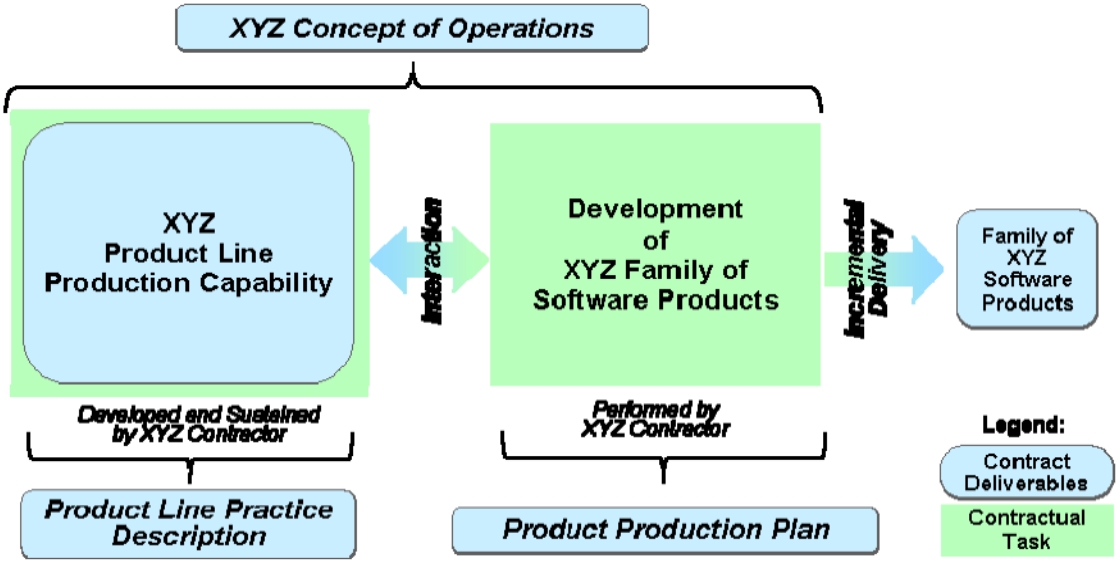

Figure 1: Conceptual View of a Product Line Acquisition

An example of a contractual deliverable that would accompany the production capability is a *product line practice description* document. Illustrative examples of organizational management, technical management, and software engineering practices that are applicable to a product line can be found in the SEI framework [Northrop 2009b].

Product developers use the production capability and its core assets to develop specific products in the product line. A product production plan documents how an individual product will be built using the core assets [Chastek 2002b].

2.2.3 Statement of Work (SOW) Tasks Example

Sample language was presented for two SOW tasks specifying the acquisition of (1) a software product line production capability and (2) a family of software products that are to be developed using the production capability. These examples are starting points (i.e., stubs) that would need to be tailored to the product line acquisition strategy and the policies of the acquisition organization.[3] The language example (*italicized*) for the SOW tasks is shown in the following two sections. The text fields delimited by the angle brackets would need to be appropriately filled in by the acquisition organization.

2.2.3.1 Task 1: Software Product Line Production Capability (PLPC)

The contractor shall develop and sustain a comprehensive software product line production capability throughout the life of the contract. The specific requirements governing this capability are described in <PLPC-specification>.

The contractor shall develop and deliver a comprehensive product line concept of operations (CONOPS) document [<CONOPS-CRDL>] and a product line practice description document [<PLPD-CDRL>] that describe how the product line will operate from an organizational and technical management perspective and how it will fully accommodate all aspects of the development and sustainment of both the <XYZ> core assets and software products.

2.2.3.2 Task 2: Products in the XYZ Software Product Line

The contractor shall use the production capability exclusively to develop and sustain a family of <XYZ> software products. A "software product" is a member of the <XYZ> software product line that corresponds to a to-be-deployed configuration of the <XYZ>. Each software product is to be built using the <XYZ> core assets in accordance with a prescribed production plan and the specified product delivery schedule [<CDRL-specifying-XYZ-product-deliverables>].

The specific requirements governing the development and sustainment of the software products in the <XYZ> family of products are described in <specification-for-XYZ-family-of-software-products>. The <XYZ> software products are to be built using the production capability in accordance with the CONOPS and supporting practices described in the product line practice description document. Moreover, the products are required to be compliant with the product line software architecture, which is itself a core asset. The core assets are to include pre-planned variation mechanisms that allow each asset to be customized to meet <XYZ> product-specific requirements.

2.2.4 Overview of a Proactive Software Product Line Acquisition Approach

Developing a suitable acquisition strategy is a key consideration in adopting a product line approach in the DoD. Of the three approaches presented in Section 2.2.1, the most challenging is approach #2 (i.e., a PM commissions a contractor to develop a government-owned product line). An example of how to implement this approach using SEI methods is depicted in Figure 2.

[3] The SEI and its representatives do not warrant RFP/contract language (or other acquisition artifacts and methods) for use in DoD or government acquisitions. Acquisition artifacts are provided as examples only. It is the responsibility of the Contracting Officer having cognizance over the acquisition to determine their appropriateness and/or suitability to a specific acquisition program.

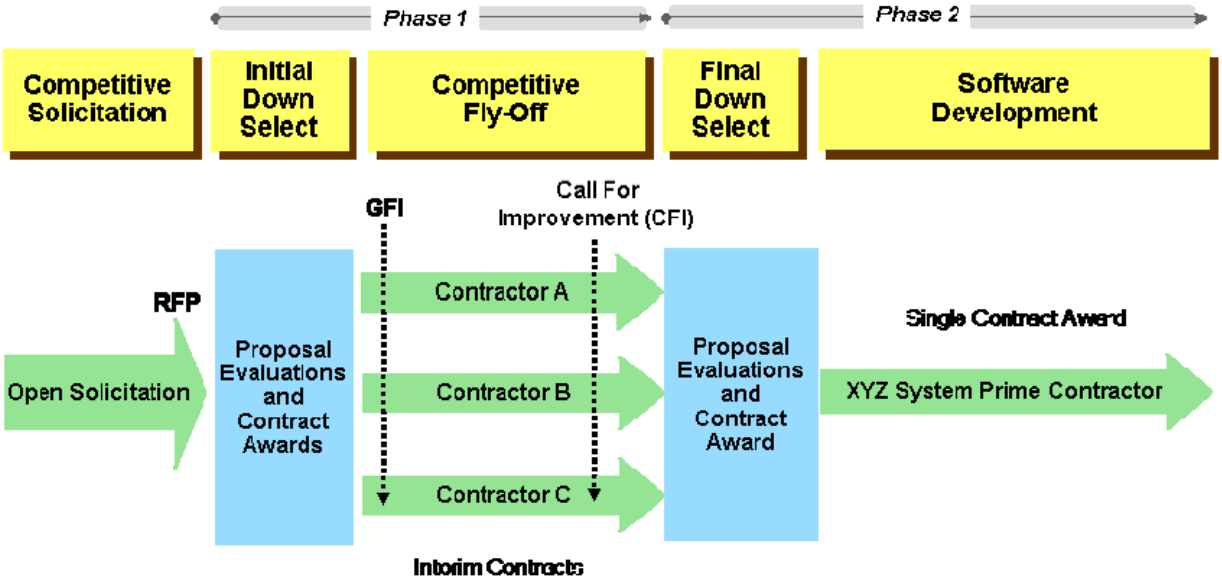

Figure 2: Overview of a Proactive Product Line Acquisition Approach

This example is commonly referred to as a *competitive down-select*. It involves competitively awarding multiple contracts (two or three) during the initial acquisition phase (Phase 1) and then conducting another "down-select" to make a single contract award (Phase 2) to the contractor demonstrating the "best-value" solution.[4]

These two acquisition phases are described in more detail in the following sections.

2.2.4.1 Phase 1 – The Competitive Fly-Off

The purpose of Phase 1 is to reduce acquisition risk by promoting competition over time. Without Phase 1, the contract award would be based on which potential supplier submits the best technical proposal, and there would be no tangible demonstration of capabilities and approach. During Phase 1 the participating suppliers are required to produce certain deliverables and participate in a set of prescribed activities as specified in the RFP/contract (see Figure 3).

[4] Best value involves awarding a contract on the basis of evaluating cost and non-cost factors to select the supplier whose proposal offers the greatest (i.e., best) value to the government in terms of performance, risk management, cost or price, and other factors. Other factors can include evaluating prototypes, supplier demonstrations, and other contract deliverables.

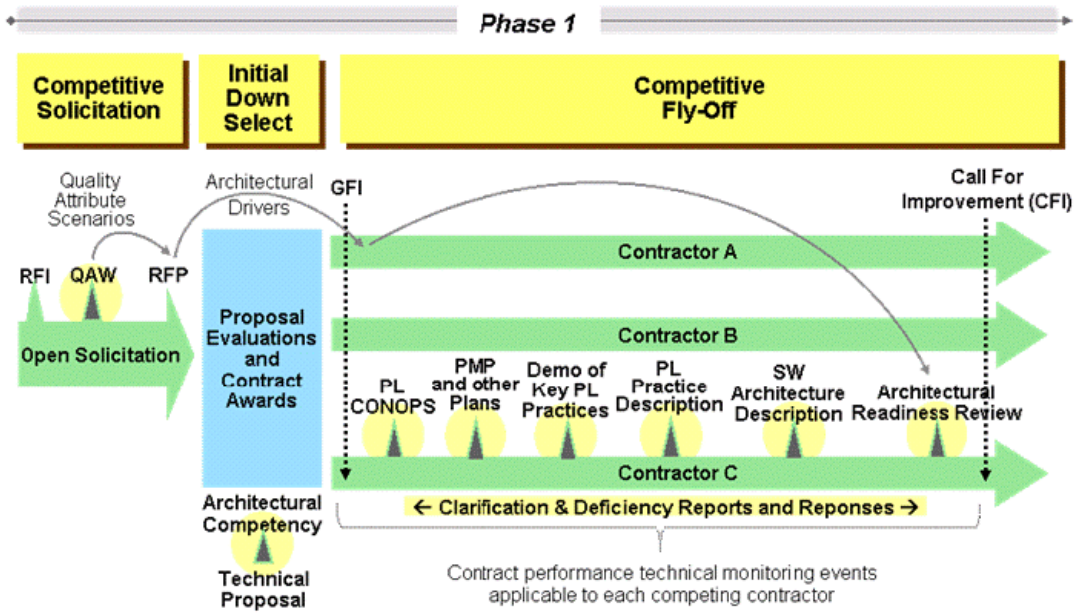

Figure 3: Overview of Phase 1 – The Competitive Fly-Off

Prior to initiating Phase 1, it is recommended that the acquisition organization conduct a Quality Attribute Workshop (QAW) to elicit and specify the key quality attributes needed for system success (e.g., performance, security, interoperability, modifiability, and other non-functional requirements) [Barbacci 2003]. It is important that these qualities be specified up front in the RFP so they can be made known to all the offerors since they will have a major influence on the design of the product line architecture.

In conjunction with the initial down-select, an architectural competency report can be required as part of each offeror's technical proposal. This has the effect of "raising the bar" on the architectural skills that are expected of each potential supplier and thus mitigating risks early because the architecture is the key to a successful product line.

As part of Phase 1, each competing supplier is required to develop and deliver several documents and participate in some prescribed activities. These deliverables and activities (in the chronological order shown in Figure 3) include

1. a product line concept of operations (CONOPS). This deliverable documents the roles and responsibilities of the various organizational elements that are involved in product line operations.
2. a project management plan (PMP) and other traditional plans. This deliverable requires that a set of traditional documents, such as a PMP, integrated master schedule (IMS), risk management plan (RMP), test and evaluation plan (TEMP) and software development plan (SDP), be expanded to address product line aspects such as core asset development and sustainment.
3. a demonstration of key product line practices. This scheduled activity requires each supplier to demonstrate a designated set of product line practices so product line strengths and chal-

lenges can be evaluated. The practices correspond to a selected subset of the 29 practice areas described in the SEI framework [Northrop 2009b].

4. a product line practice description. This deliverable describes the specific product line practices that a supplier proposes to use as part of its technical solution approach.
5. a software architecture description document. This deliverable requires each supplier to provide a summary description of its product line architecture and to document the relevant views, and add information that applies to more than one view. A minimum of three types of views of the architecture are required: module views, component-and-connector views, and allocation views [Clements 2002b]. This documentation is a prerequisite for conducting an architectural readiness review and an evaluation of the product line software architecture.
6. an architectural readiness review (ARR). This activity involves (1) walking through several quality attribute scenarios for the purpose of validating the suitability of the architectural views that are part of the architecture description document, and (2) determining the adequacy of the architecture documentation to support a follow-on software architecture evaluation using the SEI Architecture Tradeoff Analysis Method® (ATAM®) [Bass 2003].

These deliverables and activities play a key role in the final down-select (i.e., source selection) that results in competitively awarding a follow-on contract (Phase 2) to develop the required production capability and associated products.

2.2.4.2 Phase 2 – The Software Product Line Development Effort

After the Phase 2 contract is awarded, there are a number of activities and deliverables that can be specified up front in the RFP/contract to further reduce acquisition risk.

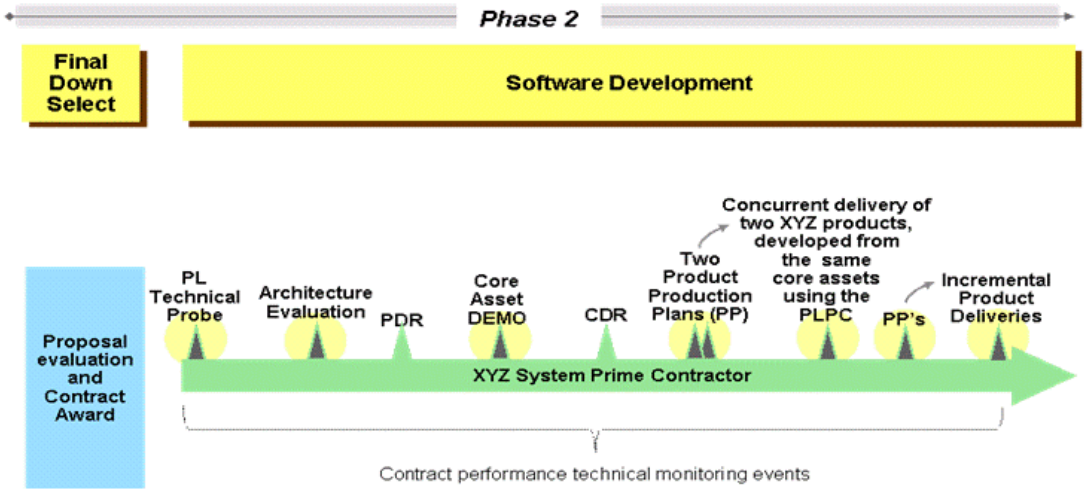

Figure 4: Overview of Phase 2 – The Software Product Line Development Effort

These Phase 2 activities and deliverables (in the chronological order shown in Figure 4) include

1. conducting an SEI Product Line Technical Probe℠ (PLTP℠). This activity involves examining an organization's readiness to adopt or ability to succeed with a software product line approach. The probe is a diagnostic tool that utilizes the SEI framework [Northrop 2009b] as

a reference model. The results of the probe are a set of findings that portray an organization's strengths and challenges with regard to a product line approach.

2. conducting an architecture evaluation. This activity involves evaluating the software product line architecture relative to quality attribute goals using the SEI ATAM. The evaluation results in the early discovery and identification of risks (and risk themes) in the architectural design so the development contractor can develop a plan for mitigating them in a timely fashion, thus avoiding extensive and costly rework downstream. If at all possible, the architecture evaluation should be completed prior to the preliminary design review (PDR). This allows the PDR team to focus on the discovered risks and how the development contractor plans to mitigate them, as opposed to performing the traditional perfunctory reviews that are characteristic of a PDR. Bergey describes the benefits of being proactive and conducting a software architecture evaluation early in the contract performance phase of a DoD acquisition along with comprehensive guidance on how to do it.[5]
3. scheduling a core asset demo. This activity requires the development contractor to demonstrate the proper functioning and operation of a selected set of assets that are critical to product line success and to demonstrate a production capability by using core assets to develop a test product.
4. concurrent delivery of two production plans. This deliverable calls for the concurrent delivery of two production plans as a precursor to the next milestone event that calls for the concurrent delivery of two corresponding products that are to be built in accordance with their respective production plans.
5. concurrent delivery of two products in the product family. This deliverable calls for the concurrent delivery of two products that are required to be built from a common set of core assets at a fixed price. This requirement precludes the developer from adopting a "clone-and-own" approach that would result in stovepiped products that would have to be separately maintained as distinct products.
6. coordinated delivery of a new production plan preceding the corresponding development and delivery of a new product in the product family. Unlike the first two products these would most likely be developed on a cost-plus-award-fee basis under a delivery order IDIQ (indefinite delivery/indefinite quantity) contract.

These activities and deliverables are illustrative examples only. They show how SEI architecture and product line methods can be effectively used to mitigate acquisition risks in a product line effort. To determine the activities and deliverables that would actually be most effective, the recommended practice is to conduct an acquisition planning workshop with stakeholders early in the acquisition planning phase (See Section 2.3).

In summary, in a proactive acquisition approach desired product line activities and deliverables are preplanned and integrated up front in the RFP. Unless an acquisition organization takes a proactive approach, it will not have an effective means for managing a product line contract and performing its technical oversight and contract monitoring responsibilities.

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[5] Bergey, J. *A Proactive Means for Incorporating an ATAM Software Architecture Evaluation in a DoD System Acquisition*. Software Engineering Institute, Carnegie Mellon University. To be published.

2.3 An Approach to Software Product Line Acquisition Planning – Larry Jones, SEI

Larry Jones presented an overview of an SEI approach to product line acquisition planning that has proven useful in a number of engagements. SEI experience has shown that all too often acquisition planning is given inadequate attention; the downstream consequences of this are frequently painful. Because of its greater complexity, a software product line acquisition calls for especially careful planning.

The SEI Acquisition Planning Workshop is a one or one-and-a-half day facilitated technical interchange among key acquisition stakeholders. It should occur early in the acquisition life cycle, in order to achieve its ultimate purpose: to reduce software acquisition risk.

Procedurally, an SEI team works in advance with the acquisition organization's point of contact to ensure that the proper stakeholders are committed to attend, that all presentations are prepared in advance, and that logistical arrangements are in order. Additionally, it is very useful if a set of key acquisition challenges can be drafted prior to the workshop by the SEI team and the point of contact. A well-thought-out set of acquisition challenges allows the SEI team to craft a set of questions to guide the discussions. During the workshop, one of the SEI team serves as a facilitator and another as a recorder to capture key discussion points, risks, and issues.

The conceptual phases of the workshop are illustrated in Figure 5 and a sample agenda is given in Table 1.

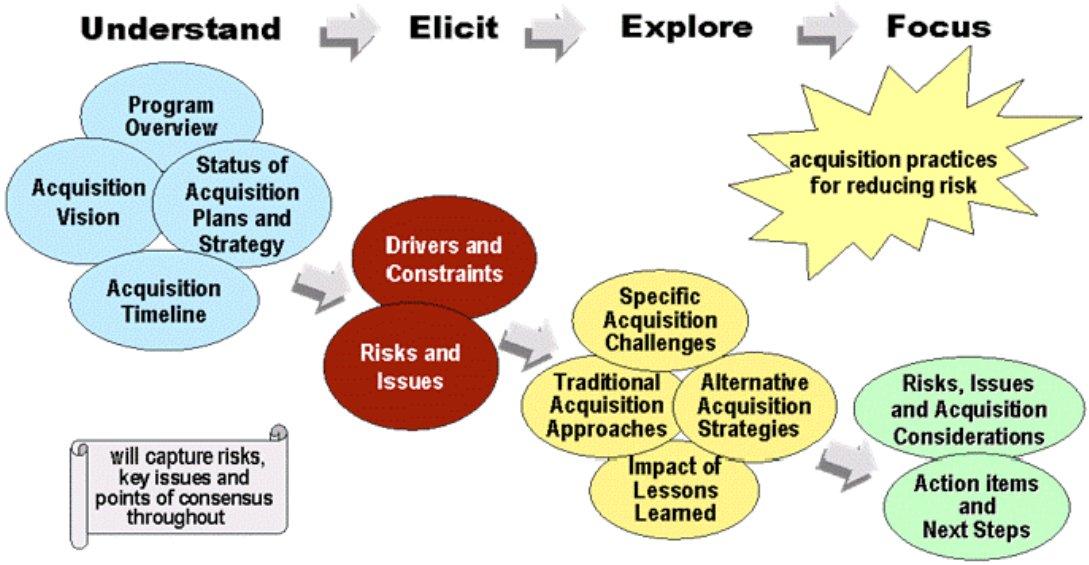

Figure 5: Conceptual Phases of a Product Line Acquisition Planning Workshop

Table 1: Sample Planning Workshop Agenda

Time	Topic	Responsibility
0800-0830	1. Welcome & Introductions	SEI/PO
0830-0900	**2. System overview and product line vision**	**PO**
0900-0915	3. Overview of acquisition organization and stakeholders	PO
0915-0930	**4. Acquisition lifecycle – program status**	**PO**
0930-1000	5. Elicitation of acquisition drivers, constraints and issues	SEI Facilitation
1000-1015	Break	
1015-1045	6. Basic product line acquisition approaches	SEI
1045-1100	7. Overview of system acquisition challenges	SEI
1100-1200	8. Elaboration* of Challenge #1	SEI Facilitation
1200-1300	Lunch	PO
1300-1400	9. Elaboration* of Challenge #2	SEI Facilitation
1400-1500	10. Elaboration* of Challenge #3	SEI facilitation
1500-1515	Break	
1515-1615	11. Elaboration* of Challenge #4	SEI Facilitation
1615-1700	12. Review and Next Steps	SEI Facilitation

*** Includes capture of risks, key issues, action items, and points of consensus**

The purpose of the *Understand* phase (steps 1-5 in the agenda) is to bring all participants up to speed on the system to be acquired and the status of the acquisition. The acquisition office will first make presentations that

- overview the system, its mission need, and context
- describe a high-level vision for the product line
- show the structure of the acquisition organization and its relationships to other key stakeholders
- summarize the status of the acquisition and the schedule

The SEI team then makes a presentation describing the different basic product line acquisition approaches that might be taken (Step 5 in the agenda). These approaches are given in Section 2.2.1.

The *Elicit* phase (Step 6 in the agenda) is a facilitated session in which acquisition drivers and constraints are elicited. These are recorded along with any risks, issues, or acquisition challenges that arise during the discussion. Typical sources of drivers and constraints include

- externally imposed constraints (e.g., joint service considerations, interoperability requirements, imposed deadlines)
- constraints adopted by the acquisition organization (e.g., dates chosen for RFP release)
- constraints imposed by other stakeholders (e.g., flight certification requirements, backward-compatibility requirements)

Once the background, constraints, and drivers have been shared, the group is ready for the *Explore* phase (Steps 7-11 in the agenda). First, the key acquisition challenges determined prior to the workshop are overviewed. Then each is explored in turn through a facilitated discussion. The

recorder captures discussion points, risks and issues. These key challenges will depend on the context of a particular acquisition. They are derived beforehand through interaction between the SEI team and the acquisition organization point of contact.

As an example, consider the situation where an existing product line effort will serve as the basis for a new competitive acquisition for a follow-on family of systems. A set of key challenges for this example might be

- How to support ongoing product development and sustainment
- How to take possession of and transition existing assets for future use
- How to initiate the new competitive acquisition
- How to manage the overall program office commitments

For each of these challenges a set of questions to drive the discussion are developed prior to the workshop. Sample discussion questions for the challenge, "How to support ongoing product development and sustainment" could include

- What is the scheduled life-time for currently deployed systems? What support will be necessary during this period? Is there a phase-out planned?
- Are there dependencies between this sustainment and the new acquisition?
- How long is the current contract in effect? Is an extension necessary to provide continuity of support? Should the scope of work be reduced (e.g., just focus on critical fixes)?

Examples of discussion questions for the challenge "How to take possession of and transition existing assets for future use" could include

- Have we validated the government data rights?
- Do we have an inventory of transitionable assets? Is additional effort necessary to package the assets?
- Do we have the necessary training materials?

To craft a set of discussion questions it is useful to consider the following general questions.

- What needs to be done?
- When will it have to be done?
- Who will be responsible for doing it?
- Where are the unknowns?
- What will be difficult about different approaches?
- What is realistic in terms of effort and time?
- What constrains our work?
- How do we make sure the work is done satisfactorily?
- How can we avoid past problems?

Throughout the discussion, stated risks and issues are recorded. Examples of such a transcription could include

- There is no common understanding of the scope of the effort.
- Because of the way the approach is currently planned, the government will be thrust into the role of system integrator.
- The schedule is unrealistic in <these areas>.
- We need to determine if a competitive down-select is the preferred approach.
- The envisioned acquisition approach is likely to result in a family of "clone-and-own" products rather than a product line.
- The Request for Information needs to be more fully developed.
- The program office does not have sufficient staff to accomplish the tasks we have identified.
- There is a gap between what the current contractor is obliged to deliver and what is needed for subsequent life-cycle support.
- Non-functional (i.e., quality) requirements are inadequately understood and inadequately documented.

Finally, the results are reviewed and follow-on actions are assigned in the *Focus* phase (Step 11 in the agenda).

- The SEI has received positive feedback from the workshops conducted thus far. Reported benefits include
  - improved identification of stakeholders
  - improved communication among acquisition stakeholders
  - improved understanding of acquisition risks
  - a better basis for a successful acquisition

2.4 The Overwatch Intelligence Center Software Product Line – Paul Jensen, Overwatch Textron Systems

Paul Jensen, chief architect at Overwatch Textron Systems, provided an update of the Overwatch Intelligence Center (OIC) software product line [Jensen 2009]. The product line provides intelligence collection, processing, and visualization capabilities to U.S. government departments and agencies. The adoption of a product line approach to software development was spurred by the recognition of the inadequacy of the single-system opportunistic reuse approach, and by the difficulty of achieving synergy across the suite of products that arose from the company's acquisition of several software companies. Overwatch developed a business case to show that a software product line (SPL) was an appropriate response to these challenges. The goal was to have every customer solution and every product be a part of the SPL within four years. Improved time to market was also a driver for adopting the product line approach.

The transition to the product line approach began in 2003, with support from the CEO, VP of engineering, and chief architect. A specific customer delivery was targeted to be the first member of the product line. The first product from the OIC SPL was released in 2005. Multiple systems have since been fielded from the product line, including two licensed products: an all-source analysis system and a signal intelligence (SIGINT) system. The first program-of-record system was fielded in 2008.

One early challenge for Overwatch was coming up with a funding model that would support core asset development (a common problem for organizations making the transition from delivery of customer-funded individual products to the delivery of members of a product line built from shared resources). A second challenge was that resources were often pulled from the core asset development effort to plug critical gaps in customer-specific product development efforts. The company had to change its funding and organizational model to one in which the responsibility for developing core assets was shared across the product development and asset development roles.

Another issue for Overwatch was the creation of a true product line architecture. In the early SPL architecture the organization neglected to address issues related to the product engineering or assembly aspects of the product, and did not define much of the infrastructure that is needed to operate a product line efficiently. Overwatch also had an extensive legacy base of some 10 million lines of code that it wanted to mine for reuse in the product line; the lack of experience in domain analysis and the lack of an architecture to support a product line hampered the creation of core assets from the legacy base. To solve these problems, the company created a new architecture called Viper. Viper is a licensable framework that enables the creation of members of the product line by composing or assembling the reusable software assets. It is the core of the OIC SPL, and it includes a software development kit to support product engineering [Jensen 2007].

The lack of experience with domain analysis (a typical situation for organizations moving from opportunistic to systematic reuse) also meant that Overwatch struggled initially with identifying the commonality and variation across current and proposed products for its product line. Variations in non-software core assets also caused some problems; requirements test artifacts, for example, weren't initially controlled as assets. These problems have all been overcome.

Remaining challenges include

- the difficulty of quantifying the value proposition of product lines in an Army acquisition context
- rapidly changing requirements due to the nature of the current fight (which lessens the accuracy of domain analysis and introduces a high rate of change in the core assets)
- the overall difficulty of balancing SPL objectives and acquisition needs (e.g., mandated events affecting the schedule, multi-program side effects)

The product line approach has yielded several benefits. The all-source analysis product was built in fewer than 90 days, with an estimated time-to-market improvement of about 2.5. More than 10 customer deliveries have been made with members of the product line, and reuse of core assets across two SIGINT system deliveries is about 70%. Anecdotal evidence suggests benefits in additional areas, such as product quality and speed of integration, but Overwatch is still working on

quantifying these values. Overall, the company made some early missteps, but is now on track with the OIC SPL and has achieved a faster time to market and more efficient and cost-effective reuse.

The lessons learned from the Overwatch experience with product line adoption include the following:

- Senior management support is critical.
- Carefully match the organizational model to the funding model.
- Product line architecture is essential.
- Address product line requirements up front.
- Put processes in place to perform domain analysis activities as early in the project life-cycle as possible.
- Agile development on product line assets is problematic; it's better suited to product development.

For the future, the plans are to improve processes, tools, and metrics while maintaining current products. A second program-of-record system will be fielded in 2009. There will also be a move to a next-generation architecture incorporating cloud computing (infrastructure as a service, platform as a service, and software as a service) and enabling composite applications composed of independent but collaborating modules.

2.5 The LVC-IA Software Product Line – Brian Kemper, U.S. Army PEO STRI

Brian Kemper, chief engineer, LT2 PEO STRI, presented an overview of product line practices and acquisition approaches employed by PEO STRI. Currently PEO STRI has three product-line-related initiatives involving each of the three domains supported by its organization: live, constructive, and virtual simulation. The Live, Virtual, Constructive Integrating Architecture (LVC-IA) provides the foundational structure and framework for linking systems in these domains into the warfighter's integrated training environment.

In the live domain, the Common Training Instrumentation Architecture (CTIA) provides a product line architecture that supports live instrumentation, Tactical Engagement Simulation Systems (TESS), targetry, domain-specific services, and associated equipment for live training within the Army's doctrine-based training process. It is the core of the Live Training Transformation-Family of Training Systems (LT2-FTS) architectural framework and LT2 repository of reusable assets. The repository, located in the LT2 portal, is intended to facilitate delivery of integrated and interoperable training solutions for live collective training across the home station, maneuver Combat Training Centers (CTCs), and deployed and joint training domains. The live training domain needed a common architecture; to meet this requirement the LT2 Initial Capability Document (ICD) provides a Joint Capability Integration and Development System (JCIDS) acquisition document and product line approach.

In the constructive domain, the One Semi-Automated Forces (OneSAF) program is the current product line initiative. OneSAF is a next-generation, entity-level simulation that supports both Computer Generated Forces (CGF) and Semi-Automated Forces (SAF) applications. This enables it to support a wide range of U.S. Army brigade-and-below constructive simulations and virtual

simulators. OneSAF's requirements were to develop a product that needed to be composable for use by multiple customers. There was also the potential to reuse the OneSAF product across other domains. This contributed to a business case in which it made sense to use a software product line approach.

In the virtual domain, the Synthetic Environment Core (SE Core) is the product line architecture example. The SE Core encompasses the Army's overarching strategy of developing virtual simulation systems that support warfighter training. The SE Core ORD (Operational Requirements Document) has interoperability and common component requirements. It was determined that a product line architecture approach was the appropriate strategy to satisfy these requirements.

Despite the fact that each of these initiatives has had a different acquisition strategy, each is guided by the application of product line practice, strategic reuse, and common standards initiatives.

Brian discussed several benefits of a software product line approach:

- SOA (Service Oriented Architecture) is starting to become important in his organization's work, and many issues about adopting SOA have already been dealt with in the product line work (e.g., reuse, acquisition culture, and budget issues).
- The product line approach is helping with interoperability of systems that are all built using the same product line.
- In the live domain, they have a mature product line with a lot of core assets, so it is easier to convince programs and program managers to use it. In the "gaming-virtual" domain the product line approach isn't as mature, so the product line is a harder sell.
- The virtual domain/SE Core is currently benefiting from the OneSAF software product line development approach in the utilization of OneSAF to replace legacy virtual simulation systems. This improves interoperability across the domain and supports the overarching LVC objectives.

Brian offered several software product line challenges and lessons learned:

- The current acquisition culture does not facilitate product line approaches. IPTs (Integrated Product Teams), trust, good software development processes, core structure, buy-in by high-level management, and enforcement are necessary to maintain and mature the product line.
- Currently, on the contractor side, product line related success is due to sophisticated technical and management talent; the product line software architect is usually a dedicated person who reports to the program manager.
- On the government side, there must be good architecture expertise; the program office must have the software architecture capability in house, otherwise the program office can't appropriately manage industry software architecture development teams and management initiatives.
- There is a need to adopt acquisition policies and processes improvements that enable product line funding and execution based on domain requirements commonality.

- The various product line initiatives at PEO STRI recognize the importance of strong configuration management (CM) processes. As multiple programs begin to leverage and extend the core assets, changes must be coordinated across the programs.
- Product line scope always seems to be a "moving target" to accommodate budget cuts and efficiencies. So there is a need to baseline product line requirements and to be ready to evolve the domain over time.
- There needs to be effective management of the product line. Brian pointed out that good metrics are important to determine cost and ROI (return on investment). LT2 uses a briefing for management showing payoff with use of the product line approach. There are programs that are now being developed with an 80-90% reuse of core assets. These successes make it easier to begin to show hard cost/savings numbers (both in development time and cost). It is also necessary to show how the product line approach will not adversely affect the program schedules. The adoption of this strategy requires complete buy-in from product managers.
- There is a need to achieve industry buy-in and participation with the specific government product line concept. This involves clearly defining how industry can profit from the approach (because companies could perceive that this affects their bottom line adversely).
- The PEO has a strategy of moving away from system development containing proprietary solutions and data. Commercial off-the-shelf (COTS) solutions have a place in the product line approach provided they can be integrated into the product line architecture.
- The PEO is developing its standard interfaces (for interoperability) in cooperation with industry. The PEO encourages COTS vendors to invest in order to become compliant with the standards.
- Education is essential for all stakeholders. Brian said, "ASSIP product line education options provide a valuable opportunity to help get stakeholders in line with the overarching architecture objectives."
- Early successes are important. It is easy for the product line domain analysis team to "go a mile wide and an inch deep" and begin to lose momentum. It is important to effectively and quickly establish an initial domain analysis; this has enabled PEO STRI to get some quality software core assets out to the product builders in a reasonable time frame.

Brian emphasized that up-front investment is necessary for a successful product line. The PM shops must commit to contributing to the base product line work (core asset set and product line architecture). In the live domain their acceptance of the need for that up-front investment is now starting to reap the benefits.

The way the Army usually works is that money comes into programs, and these programs usually don't have enough dollars to do what they need to do functionally. So it is difficult to convince the programs to provide the up-front investment required to support a product line approach, especially when the PM may not realize the benefit until a year or two down the road. The challenge is to find a way to convince PMs to embrace the product line approach and apply funds to the product line support. Organizational buy-in at the PEO and O-6 levels is essential to the successes seen across live, virtual, and constructive domains at PEO STRI.

Brian provided several examples of product line acquisition enablers for the LT2 program:

- a specific LT2 product line funding line
- an Integration and Interoperability Advisory Board (I2AB) that
  - facilitates the integration and interoperability of PEO STRI training systems combining technical and programmatic perspectives
  - provides architecture and technical recommendations across the PEO by applying a horizontal/vertical integration approach
  - leverages PEO product line assets across the PEO to support interoperability across the Army and other services
- life-cycle configuration management as a key to maintaining product line integrity
- a project manager with "product line vision" who is willing to think outside the "acquisition box" while making sure always to address how this benefits the soldier

Brian concluded with a quote from Dr. James T. Blake, Program Executive Officer, U.S. Army PEO STRI, that demonstrates the organizational commitment to software product lines.

> *The current operational environment requires quickly adaptable systems for the Warfighter. To better support this challenging environment, PEO STRI is adopting the deliberate and disciplined tenets of Product Line Acquisition to maximize adaptability.*
>
> *Product Line Acquisition tenets emphasize re-use of components, synchronizing the production of products, and seamless interoperability between components, products, and systems. These tenets bring the Live, Virtual, and Constructive domains together to facilitate interoperability and integration (I2).*

2.6 Electronic Warfare Product Line – Don Snelgrove, BAE Systems

Don Snelgrove, Director of the Product Centered Organization of BAE Systems, Electronic Solutions, Nashua, N.H., made a presentation on behalf of the Electronic Solutions line of business. This product line is under development at BAE Systems, Hudson, N.H.

BAE Systems develops a wide range of EW (electronic warfare) products for advanced defense and aerospace systems. Recent examples include the F-22 and Joint Strike Fighter. EW products may be used to detect, identify, locate, signal process, perform threat analysis, or jam other radio frequency (RF) emissions. Customers include many DoD services, joint services, and foreign military.

Most of these applications implement SIGINT (signal intelligence) functionality. On the front end, these systems sense RF emissions, capture those signals, process them, and provide the information for display in a cockpit or ground station. BAE is responsible for the entire product—software, firmware, and hardware.

2.6.1 Issues and Challenges of the Product Line Approach

BAE's product line effort emerged in the late 1990s from a series of cost-plus contracts that ended when higher-than-projected costs were reached. Recognizing commonality across many of their systems, BAE Systems created a software architecture for SIGINT. The initial architecture did not cover the entire EW mission area—funding was not sufficient to make this feasible. However,

BAE Systems adopted a component strategy looking at the geo-location, signature identification, and other high-value domains. Development of the common architecture used in-house project funds, with support from the vice president within BAE Systems who also directed use of the common architecture.

Over a series of developments, BAE Systems added building blocks and reached a critical mass in terms of capabilities for the EW mission area. Building on this, BAE Systems established a product-centered organization that considers not only software, but also firmware for field programmable gate array (FPGA) hardware. This firmware tends to be higher cost and more difficult to port than software. So extending portability attributes through the common architecture is a significant gain in terms of non-recurring expenses.

BAE Systems' product line approach involves coupling project support with focused IRAD (internal research and development) to enhance the core asset base. Decisions about where to apply the IRAD effort come from marketing, which identifies the emerging trends and seeks to address them in advance of actual projects. Under this approach, the core asset base includes software + hardware (not antennas) + firmware. A typical program is now a mix of core assets plus new software, hardware, or firmware.

2.6.2 Impact of the Product Line

The collection systems within the product line now have a broad customer base. BAE Systems sees its objectives as refreshing and extending the core asset base for hardware and software. A typical project anticipates very high reuse of core assets, although actual reuse percentages can vary depending upon the project type. One difficulty is in measuring the profit achieved to investment made—how critical is the core asset base to the organization?

The product line approach reduces recurring costs. It also improves system producibility. Common software contributes to common hardware buys, increasing the numbers of buys of circuit cards for multi-program use, rather than individual program use. This provides leverage across hardware and firmware. Programs also have realized gains in integrated engineering—where hardware design and manufacturing, and software development work together to maximize reuse.

BAE Systems has developed a concept referred to as "X + Y + Z." This concept categorizes software on a product as being either X (from core assets), Y (not currently from core assets, but showing potential), or Z (not feasible as core assets). A typical bid closely scrutinizes those capabilities in the Y for evolution to core assets. The term *delta-Y,* or ΔY, refers to those capabilities that with add-on funds, can be made a core asset.

BAE Systems has not solved all the problems of using core assets. Some of the issues being grappled with are

- personnel sharing. Programs need common resources and sharing of personnel, so personnel no longer "belong" to a project but are a part of the cadre of engineers in the product-centered organization.
- security. Different project security levels use shared code. A question is, "How do you maintain software code at security levels dictated by varying security classification guides?"

- technology refresh. Hardware technology may last for four years. A challenge is to select the new technology with IRAD funds so that future products can share a common FPGA platform.
- program versus business interest needs. Managers recognize the need for ΔY but desire to drive costs down. More ΔY increases costs for the individual program, and savings from reuse of previous ΔY → X core assets is often not recognized.
- organization. BAE Systems must recognize design versus architecture versus product line architecture staff. The latter is a small number with a chief architect across programs. The organization also includes technical leads (called technical stewards) across eight areas (domain or hardware specialties). Stewards have a high degree of awareness of cross-program needs, consistent with the product line vision. A concern is how to develop chief architect skills.
- investment. IRAD investment must address the next generation architecture and look downstream for 3–5 years.

2.6.3 Recommendations

Don concluded with the following recommendations:

- Use IRAD funding for initial platform development.
- Strong leadership, both technical and management, is required.
- Technical leads must maintain the product line approach, but must balance between not-too-little or too-much effort on product line enhancements.
- Analyze financial costs and benefits—for example, SLOC (source lines of code) saving, costs.
- Migrate test procedures from project-specific assets to core assets. Use IRAD money to fund a common test framework. Do continuous integration and automating of builds.
- Individual program development efforts lead to branching in the code baseline for adaptation. Develop configuration management procedures to merge these branches back into the baseline. The cost of merging and the costs of baseline adaptations are part of product line sustainment.
- A technical steward should manage both the baseline evolution through product development and the need for rapid turnaround of new requests.

2.7 The RangeWare Software Product Line – Ed Dunn, NUWC

Ed Dunn of NUWC, Newport, offered a brief status update of a developing product line for undersea test and training ranges. An expanded summary of Ed's remarks is available to support official DoD activities through email to Ed at edward.dunn@navy.mil.

3 A Summary of the Facilitated Discussions

Following the presentations, the group participated in a facilitated discussion. A summary follows.

3.1 Discussion Topic: To achieve product line success: What do I (as a supplier) want in a program office? What do I (as an acquisition office) want in a supplier?

Two key items were identified for the supplier's "wish list." Suppliers would like

1. to know the program's acquisition strategy, the funding available, and the roadmap for the product line opportunity
2. to have a Program Office that is steady on course and speaks with a consistent voice from day to day

It was recognized that the latter point may be difficult to achieve because of the military assignment cycle. This cycle sometimes results in military program managers who do not take a strategic view, and software product lines are a strategic effort. A change in leadership may also mean a change in strategy.

When considering product lines, both suppliers and program offices should understand that a many-to-many relationship is involved: The program office wants multiple contractors to foster competition; suppliers want multiple opportunities. In particular, suppliers who have created a product line want to use the product line products with modification on multiple systems and not be restricted by the data rights.

The issue of competing data rights was a primary concern. Depending on how data rights are addressed, they could limit a supplier's choice of even bidding on a product line opportunity. Simply put, suppliers want to be able to use their intellectual property elsewhere; the acquirer wants the data rights. As one participant put it, "If I have to put up IRAD money I need to be able to recover it. The government needs to provide some incentive for me to incur the IRAD cost. Also if the government pays for the product line, I want to be able to ensure future business—not have restricted data rights." There has to be a business case that shows it makes sense to surrender the intellectual property.

This led to a discussion of the question, "How does the company who created the original core assets not suffer once the data rights are given to other suppliers?" Some suppliers felt that their knowledge of the application domain and the product line itself would provide the necessary competitive advantage. Others felt that this may not be the case, saying that emulating an idea is much easier than coming up with the original.

There were enough loose threads in this discussion for several people to request a special breakout session at a future workshop devoted to product line data rights. Setting aside the data rights issue, the discussion led to the next topic.

3.2 Discussion Topic: What's in it for the supplier? What is needed to incentivize suppliers?

This question had several sub-parts:

- What incentives can the government provide to encourage suppliers to propose a product line approach even if it is not a hard requirement?
- What incentives can the government offer to encourage suppliers to respond to a product line acquisition?
- What are the barriers from a supplier perspective? How can these barriers be addressed?

One incentive for suppliers would be the existence of a large enough market for derived products to recoup the investment. If the government is funding the product line work then the length of the contract becomes important.

Several suggestions were brought up about promoting product lines. One was for ASSIP to sponsor workshops for government (and possibly supplier) contracting officers to educate these acquisition individuals on product lines. Other educational workshops were discussed that would explore areas such as product line cost estimation, product line metrics, and the data rights issues, and include breakout sessions for special interests. It was suggested that since systems-of-systems are likely candidates for a product line approach this might be an incentive to have more suppliers participate in product line workshops. Bob Schwenk said that ASSIP will support workshops with contractors to discuss these various issues (plus FARS and DFARS). Participants urged that these workshops should involve the legal people.

Training was suggested as another avenue to provide a push on the government side. Many organizations have mandatory, self-paced training programs. Product line awareness could be included within this structure. On the industrial-base side, while some schools educate students in product lines, this is typically at the graduate level and is not widespread.

Distributing return on investment data throughout the Army would help attract attention. There should be a communications strategy targeting different media that reach a broad audience, including senior leaders.

An indirect push for product lines is the Army's Software Blocking. Software Blocking mandates interoperability and backwards compatibility. Theater needs also drive program managers to move towards common interfaces. A software product line approach may provide an answer for some of these challenges.

Contracting strategies to promote product lines were discussed. One participant suggested that product lines could be encouraged through use of cost-plus incentive fees. It was pointed out that use of an award fee affects near-term behavior, but product lines are about the long term. Program offices are starting to look at IDIQ-type contracts. Another suggested option to encourage a long-term perspective was to use RDT&E money (versus production money). In the words of one participant, "Most contracting officers don't think of buying software in the same way as they think about buying, say, tanks. Why not long-range funding for software along the lines of contracts for test range maintenance?"

As in any lively discussion, interesting points are made that don't strictly follow the original question. These points included

- Technical evaluation criteria. In reference to what to include in sections M and L of an RFP (see Section 2.2), Bob Schwenk observed, "There has to be a relationship with our contracting offices; we don't do a good job of spelling out the criteria." When considering past performance, it is about results, not just following a checklist.
- Cost estimation and metrics. The SEI has the SIMPLE Model for product line cost estimation [Clements 2005, SIMPLE 2009]. A good subject for a future workshop would be product line metrics.

4 Summary

The 2009 Army Product Line Practice Workshop explored the product line practices of organizations in the Army community through sharing of experiences. Thirty-five people attended, representing 22 organizations. This workshop demonstrated a continuance of the trend revealed during the most recent workshops: namely, software product line practice is becoming a reality in the Army and DoD. All the presentations were based on experience rather than plans or speculation. Benefits are being quantified. The central role of software architecture was reaffirmed. Challenges and experience-based solutions were discussed, but these discussions highlighted the increasing use and acceptance of software product line practice.

The most newsworthy item from the workshop is the emergence of DoD suppliers that have successfully addressed the oft-cited barriers of business justification and funding for a product line approach for government business. They have built a business case for the approach, and have been able to establish a viable strategy for funding the development and maintenance of a core asset base. That this strategy has been made to work across a set of products developed for different customers is a significant achievement. (Organizations frequently encounter difficulties when trying to move from a customer-driven, product-specific funding model to one in which at least some of the funds are allocated to the creation and maintenance of reusable artifacts that can be shared across several product development efforts. The framework practice area on funding a product line describes the challenges and provides several examples of funding models [Northrop 2009b].)

Participants also noted other appealing aspects of today's product line successes.

- Given the right leadership, a software product line approach can grow across formerly stovepiped development efforts.
- A software product line approach allows a supplier to respond quickly to an RFP; the response is itself a core asset.
- Licensing the software product line can be part of a viable business strategy.
- A software product line approach should be considered a journey; benefits can accrue even if the first attempt isn't perfect.

To be sure, there are still challenges, as evidenced by the discussion on the importance of the data rights issue for both suppliers and acquirers. But the underlying attitude was that product lines are real and appropriate; now people want to know how to buy and fund them.

The post-workshop critique was very positive. Participants universally agreed on the value of the workshop and on the need for the SEI to continue work in software product lines and provide related support to the DoD. The consensus among long-time attendees was that this workshop bettered the 11 previous DoD workshops, both in terms of quality of presentations and participants and in the progress reported. The participants recommended that the ASSIP sponsor follow-on workshops this year on specific product line topics and another general workshop next year. Bob Schwenk, ASA ALT, was equally positive and agreed with the recommendations.

If you have any comments on this report or are using a product line approach in the development or acquisition of software-intensive systems for the DoD and would like to participate in a future workshop, please send email to Linda Northrop at lmn@sei.cmu.edu.

References/Bibliography

URLs are valid as of the publication date of this document.

[Barbacci 2003]
Barbacci, M.; Ellison, R.; Lattanze, A.; Stafford, J.; Weinstock, C.; & Wood, W. *Quality Attribute Workshops, 3rd Edition* (CMU/SEI-2003-TR-016 ADA418428). Software Engineering Institute, Carnegie Mellon University, 2003.
http://www.sei.cmu.edu/publications/documents/03.reports/03tr016.html

[Bass 1997]
Bass, L.; Clements, P.; Cohen, S.; Northrop, L.; & Withey, J. *Product Line Practice Workshop Report* (CMU/SEI-97-TR-003, ADA327610). Software Engineering Institute, Carnegie Mellon University, 1997. http://www.sei.cmu.edu/pub/documents/97.reports/pdf/97tr003.pdf

[Bass 1998]
Bass, L.; Chastek, G.; Clements, P.; Northrop, L.; Smith, D.; & Withey, J. *Second Product Line Practice Workshop Report* (CMU/SEI-98-TR-015, ADA354691). Software Engineering Institute, Carnegie Mellon University, 1998.
http://www.sei.cmu.edu/pub/documents/98.reports/pdf/98tr015.pdf

[Bass 1999]
Bass, L.; Campbell, G.; Clements, P.; Northrop, L.; & Smith, D. *Third Product Line Practice Workshop Report* (CMU/SEI-99-TR-003, ADA361391). Software Engineering Institute, Carnegie Mellon University, 1999.
http://www.sei.cmu.edu/pub/documents/99.reports/pdf/99tr003.pdf

[Bass 2000]
Bass, L.; Clements, P.; Donohoe, P.; McGregor, J.; & Northrop, L. *Fourth Product Line Practice Workshop Report* (CMU/SEI-2000-TR-002, ADA375843). Software Engineering Institute, Carnegie Mellon University, 2000.
http://www.sei.cmu.edu/publications/documents/00.reports/00tr002.html

[Bass 2003]
Bass, L.; Clements, P.; & Kazman, R. *Software Architecture in Practice,* 2nd ed. Addison-Wesley, 2003. http://www.sei.cmu.edu/publications/books/

[Bergey 1998]
Bergey, J.; Clements, P.; Cohen, S.; Donohoe, P.; Jones, L.; Krut, R.; Northrop, L.; Tilley, S.; Smith, D.; & Withey, J. *DoD Product Line Practice Workshop Report* (CMU/SEI-98-TR-007, ADA346252). Software Engineering Institute, Carnegie Mellon University, 1998.
http://www.sei.cmu.edu/pub/documents/98.reports/pdf/98tr007.pdf

[Bergey 1999]
Bergey, J.; Campbell, G.; Clements, P.; Cohen, S.; Jones, L.; Krut, R.; Northrop, L.; & Smith, D. *Second DoD Product Line Practice Workshop Report* (CMU/SEI-99-TR-015, ADA375845). Software Engineering Institute, Carnegie Mellon University, 1999.
http://www.sei.cmu.edu/pub/documents/99.reports/pdf/99tr015.pdf

[Bergey 2000a]
Bergey, J.; Campbell, G.; Cohen, S.; Fisher, M.; Jones, L.; Krut, R.; -Northrop, L.; O'Brien, W.; Smith, D.; & Soule, A. *Third DoD Product Line Practice Workshop Report* (CMU/SEI-2000-TR-024, ADA387259). Software Engineering Institute, Carnegie Mellon University, 2000.
http://www.sei.cmu.edu/publications/documents/00.reports/00tr024.html

[Bergey 2000b]
Bergey, J.; Fisher, M.; Gallagher, B.; Jones, L.; & Northrop, L. *Basic Concepts of Product Line Practice for the DoD* (CMU/SEI-2000-TN-001, ADA375859). Software Engineering Institute, Carnegie Mellon University, 2000.
http://www.sei.cmu.edu/publications/documents/00.reports/00tn001.html

[Bergey 2001]
Bergey, J. et al. *Fourth DoD Product Line Practice Workshop Report* (CMU/SEI-2001-TR-017, ADA399205). Software Engineering Institute, Carnegie Mellon University, 2001.
http://www.sei.cmu.edu/publications/documents/01.reports/01tr017.html

[Bergey 2003]
Bergey, J. et al. *Fifth DoD Product Line Practice Workshop Report* (CMU/SEI-2003-TR-007, ADA416733). Software Engineering Institute, Carnegie Mellon University, 2003.
http://www.sei.cmu.edu/publications/documents/03.reports/03tr007.html

[Bergey 2004]
Bergey, J.; Cohen, S.; Jones, L.; & Smith, D. *Software Product Lines: Experiences from the Sixth DoD Software Product Line Workshop* (CMU/SEI-2004-TN-011 ADA443501). Software Engineering Institute, Carnegie Mellon University, 2004.
http://www.sei.cmu.edu/publications/documents/04.reports/04tn011.html

[Bergey 2005]
Bergey, J.; Cohen, S.; Donohoe, P.; & Jones, L. *Software Product Lines: Experiences from the Seventh DoD Software Product Line Workshop* (CMU/SEI-2005-TR-001 ADA441835). Software Engineering Institute, Carnegie Mellon University, 2005.
http://www.sei.cmu.edu/publications/documents/05.reports/05tr001.html

[Bergey 2006]
Bergey, John & Cohen, Sholom. *Product Line Acquisition in a DoD Organization–Guidance for Decision Makers* (CMU/SEI-2006-TN-020). Software Engineering Institute, Carnegie Mellon University, 2006.
http://www.sei.cmu.edu/publications/documents/06.reports/06tn020.html

[Brownsword 1996]
Brownsword, L. & Clements, P. *A Case Study in Successful Product Line Development* (CMU/SEI-96-TR-016, ADA315802). Software Engineering Institute, Carnegie Mellon University, 1996. http://www.sei.cmu.edu/pub/documents/96.reports/pdf/tr016.96.pdf

[Chastek 2002a]
Chastek, G., ed. *Proceedings of the Second Software Product Lines Conference (SPLC2)* (Lecture Notes in Computer Science [LNCS] volume 2379). San Diego, CA, Aug. 2002. Springer-Verlag, 2002.

[Chastek 2002b]
Chastek, G. & McGregor, J. *Guidelines for Developing a Software Product Line Production Plan* (CMU/SEI-2002-TR-006 ADA406687). Software Engineering Institute, Carnegie Mellon University, 2002. http://www.sei.cmu.edu/publications/documents/02.reports/02tr006.html

[Clements 2001]
Clements, P.; Donohoe, P.; Kang, K.; McGregor, J.; & Northrop, L. *Fifth Product Line Practice Workshop Report* (CMU/SEI-2001-TR-027, ADA272355). Software Engineering Institute, Carnegie Mellon University, 2001.
http://www.sei.cmu.edu/publications/documents/01.reports/01tr027.html

[Clements 2002]
Clements, P. & Northrop, L. *Software Product Lines: Practices and Patterns*. Addison-Wesley, 2002.

[Clements 2002b]
Clements, P.; Bachmann, F.; Bass, L.; Garlan, D.; Ivers, J.; Little, R.; Nord, R.; & Stafford, J. *Documenting Software Architectures: Views and Beyond.* Addison-Wesley, 2003.

[Clements 2005]
Clements, Paul C.; McGregor, John D.; & Cohen, Sholom G. *The Structured Intuitive Model for Product Line Economics (SIMPLE)* (CMU/SEI-2005-TR-003 ADA441881). Software Engineering Institute, Carnegie Mellon University, 2005.
http://www.sei.cmu.edu/publications/documents/05.reports/05tr003.html

[Cohen 2002]
Cohen, S.; Dunn, E.; & Soule, A. *Successful Product Line Development and Sustainment: A DoD Case Study* (CMU/SEI-2002-TN-018, ADA407788). Software Engineering Institute, Carnegie Mellon University, 2002.
http://www.sei.cmu.edu/publications/documents/02.reports/02tn018.html

[Cohen 2004]
Cohen, S.; Zubrow, D.; & Dunn, E. *Case Study: A Measurement Program for Product Lines* (CMU/SEI-2004-TN-023 ADA441818). Software Engineering Institute, Carnegie Mellon University, 2004. http://www.sei.cmu.edu/publications/documents/04.reports/04tn023.html

[Cohen 2007]
Cohen, S. & Capolongo, K. *A Product Line Architecture for Army Aviation Diagnostics and Maintenance: Views and Evolution*. SATURN 2007 Conference. Pittsburgh, PA, May 2007. http://www.sei.cmu.edu/architecture/saturn/2007/presentations/Cohen.pdf

[Donohoe 2000]
Donohoe, P., ed. *Software Product Lines: Experience and Research Directions, Proceedings of the First Software Product Line Conference (SPLC1)*. Denver, CO, Aug. 28-31, 2000. Kluwer Academic Publishers, 2000.

[Geppert 2008]
Geppert, B. & Pohl, K. eds. *SPLC 2008: Proceeding of the 12th International Software Product Lines Conference*. Limerick, Ireland, 8–12 September, 2008. Los Alamitos, CA: Institute of Electrical and Electronics Engineers, Inc., 2008.

[Goerthert 2003]
Goerthert, W.; & Fisher, M. *Deriving Enterprise-Based Measures Using the Balanced Scorecard and Goal-Driven Measurement Techniques* (CMU/SEI 2003-TN-024, ADA418401). Software Engineering Institute, Carnegie Mellon University, 2003. http://www.sei.cmu.edu/publications/documents/03.reports/03tn024.html

[IEEE 2007]
Proceedings of the 11th International Software Product Line Conference. Kyoto, Japan, 10–14 September, 2007. Los Alamitos, CA: Institute of Electrical and Electronics Engineers, Inc., 2007.

[Jensen 2007]
Jensen, Paul. "Experiences with Product Line Development of Multi-Discipline Analysis Software at Overwatch Textron Systems,"35–43. *SPLC 2007: Proceedings of the 11th International Software Product Line Conference*. Kyoto, Japan, Sept. 2007. Los Alamitos, CA: Institute of Electrical and Electronics Engineers, Inc., 2007.

[Jensen 2009]
Jensen, Paul. "Experiences with Software Product Line Development." *CrossTalk 22*, 1 (January 2009): 11–14.

[Kazman 2003]
Kazman, R.; Nord, R. & Klein, M. *Life-Cycle View of Architecture Analysis and Design Methods (*CMU/SEI-2003-TN-026, ADA421679) Software Engineering Institute, Carnegie Mellon University, 2003. http://www.sei.cmu.edu/publications/documents/03.reports/03tn026.html

[Krueger 2002]
Krueger, C. W. "Easing the Transition to Software Mass Customization," 282-293. *Proceedings of the 4th International Workshop on Software Product Family Engineering*. Bilbao, Spain, Oct. 2001. Springer-Verlag, 2002.

[Nord 2004]
Nord, R., ed. *Proceedings of the Third International Software Product Lines Conference (SPLC 2004)* (Lecture Notes in Computer Science [LNCS] volume 3154). Boston, MA, Aug.-Sept. 2004. Springer-Verlag, 2004.

[Northrop 2008]
Northrop, L. *Software Product Line Essentials*.
http://www.sei.cmu.edu/productlines/essentials/essentials_7_08.pdf (2008).

[Northrop 2009a]
Northrop, L. *SEI Army Software Product Line Workshop*.
http://www.sei.cmu.edu/ productlines/Armyworkshop/army-spl-workshop-spl-overview.pdf (2009).

[Northrop 2009b]
Northrop, L. & Clements, P. *A Framework for Software Product Line Practice, Version 5.0*
http://www.sei.cmu.edu/productlines/framework.html (2009).

[Obbink 2005]
Obbink, H.; & Pohl, K. *Software Product Lines, Ninth International Conference, SPLC 2005 Proceedings*, (Lecture Notes in Computer Science [LNCS] volume 3714). Rennes, France, Sept. 2005. Springer-Verlag, 2005.

[O'Brien 2006]
O'Brien. L (Ed.). *Proceeding of the 10th International Software Product Lines Conference*, SPLC 2006 Proceedings, Baltimore, MD, Aug. 2006. IEEE Computer Society, ISBN 0-7695-2599-7, 2006.

[SIMPLE 2009]
Structured Intuitive Model for Product Line Economics.
http://www.sei.cmu.edu/productlines/economics_spl.html (2009).

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The Carnegie Mellon Software Engineering Institute held the U.S. Army Product Line Practice Workshop on February 12, 2009. The workshop was a hands-on meeting to share Army and DoD product line practices, experiences, and issues and to discuss specific product line practices and operational accomplishments. Participants reported encouraging progress on Army software product lines. This report synthesizes the workshop presentations and discussions.

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